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PREFACE

During the period of nearly two years following the AFSC/Rand Symposium on Remotely Piloted Vehicles, numerous meetings were held with senior engineering and management personnel of most large aerospace companies on the strike concepts offered during the Symposium. A favorite topic discussed was how to make and operate RPVs much less expensively than aircraft (assuming an airplane with the same performance, weight and size as the RPV). From these discussions, assurance was gained that it could indeed be possible to achieve RPV systems with remarkably low life-cycle costs. This paper reflects the ideas formulated and validated in these talks.

The theme stressed during the RPV Symposium in 1970 was the realization that the technologies necessary for tactical RPVs have been demonstrated with the exception of the ability to provide low cost vehicles. In recent years the military-oriented aerospace industries in the U.S. have, almost without exception, not been able to produce truly inexpensive hardware.* It has been said, perhaps with some exaggeration, that RPVs should be designed and produced by a non-aerospace industry; namely, a large well-known toy manufacturer. Nevertheless it may not be a simple matter to realize the kinds of low cost RPVs proposed herein. During discussions with an engineer from a large aerospace firm on this subject, he commented that it would be quite difficult for his designers and managers to change from their expensive, detailed practices. He thought the only way his firm

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*One exception is noteworthy: High velocity aerial targets for the Army with fuselages of paper tubing identical to the cores of carpet rolls and with three rockets readily available as motors of 2.75 inch rockets for its booster thrust.

could achieve a low cost philosophy was to establish a design group at a location removed from their main plant comprised of engineers who had no experience on military aerospace hardware. Let us hope that human nature allows enough flexibility and inventiveness in experienced engineers to make such drastic steps unnecessary.

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LOW COST TACTICAL RPVs

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This paper discusses the potential for providing low cost tactical remotely piloted vehicles (RPVs), with emphasis on development of an unconstrained innovative approach in establishing their logistic and maintenance characteristics which can significantly influence the overall design of RPVs and their support aerospace ground equipment (AGE). It is hoped that this paper will encourage critical examination of various design and support system options, with the goal of initiating changes in the expensive methods currently used to obtain military hardware.

The RPVs discussed here are primarily those which are ground-launched, controlled from a ground station even when the RPVs are a long distance away (e.g., more than 100 mi), and returned for recovery and reuse; however, most of the ideas expressed are also applicable to other possible variants of RPVs, such as expendable vehicles and those launched and controlled from aircraft (for example, Condor). Indeed, a low cost philosophy should be adopted for all kinds of RPVs.

Requirements for RPVs should direct that low life-cycle costs be provided for these new tactical weapon systems as well as defining the expected mission performance goals. The motivation to reduce costs--not only the initial investment costs but also those associated with operation, maintenance, and logistics--should dominate the actions taken by the R&D community in response to operational requirements. Specifically,

this means that a new maintenance and logistics approach should be taken for the support of RPVs; the kinds of systems now used to support military aircraft should not be envisioned when satisfying RPV requirements. We should insist on simplified support systems--those which can provide the lowest life-cycle costs. As one example, we should strive for RPV system concepts which will require a minimum number of skilled personnel, since manpower constraints on military systems may be expected to be much more severe in the future than in the past.

Costs of an unmanned flying vehicle can be reduced in many ways. A principal method is to establish practical yet minimal performance requirements for the vehicle's maximum airspeed, payload, versatility, and the environmental conditions under which it must operate. Strike RPVs will usually be flown below 20,000 ft; they should not be required to operate at 40,000 or 50,000 ft. We must keep in mind that RPVs are not expected to survive a large number of sorties since they will be used primarily, and perhaps solely, in the most heavily defended environments. Therefore, they will not be expected to fly more than 10 to 20 sorties. Many subsystems will be required to operate perfectly at all times; an occasional failure of an essential subsystem may cause a catastrophic loss. Therefore, higher operational losses can be expected for RPVs than for manned aircraft due to accidents other than losses related to hostilities. Furthermore, since RPVs need not satisfy safety of flight requirements, man-rated qualities do not have to be designed into the vehicles. Thus it can be concluded that an entirely different philosophy of design can be accepted for RPVs than is used for manned aircraft.

If we consider all RPVs as expendable, those that can be recovered and flown again may be called "resusable expendables." They may be categorized as a non-aircraft class of military hardware--similar to a round of ordnance or other weapon--and an appropriate design philosophy followed. Because many RPVs will be necessary to be effective in an important conflict, we should think in terms of automated fabrication and high production rates--rates typical of the automobile industry or the production of ordnance.

There could be cost advantages in designing RPVs in a modular form, that is, from major components which can be easily and rapidly removed and replaced when necessary. Some components can be considered throw-away items and when they are damaged or fail they can be replaced easily by either new components or usable ones from damaged vehicles. The concept of cannibalization could be introduced into RPV systems, regardless of how inappropriate it is for aircraft maintenance procedures. The major components could be assembled at a staging area close to the launch site, having been stored in convenient-sized packages and shipped by air or other means to the staging area. The assembling process must be made simple, consisting of installation of a series of bolts or screws and attachment of electrical connections, fuel lines, hydraulic lines, etc. The engine pod should be a single module which can be replaced without excessive time or skill. The necessary maintenance skills should be limited, perhaps to the use of torque wrenches and safety wiring. This will require much imagination and innovation in the design of RPV air-frames. The potential of a modular concept cannot be ascertained without design and evaluation of low cost components which allow only minimal repairs, if any.

Combat elements will need replacement RPVs frequently during intense conflicts extending over weeks and months, and the loss rate may be as high as 10 or 20 percent. Thus the modular approach also looks attractive as a good way to ease the efforts needed to get many replacement RPV components to the operating theater. Also, it may be highly appropriate to keep the physical size of the vehicles small. If a modular approach is introduced, the Air Force could conceivably get wings from one contractor, fuselages from another, etc., with an effective systems integration management organization. (Perhaps electronic companies can be the RPV prime contractors!) This modular approach may be vital if RPVs are deployed to small airfields only suitable for small cargo aircraft or if they are transported by trucks to remote sites. Considerable transportation support may be needed, but the resources spent on logistics of this kind will be less than those required to provide many skilled mechanics to repair and recondition a limited number of RPVs. The transportation problem will exist to some degree regardless of the maintenance and design concepts adopted because of the expected RPV loss rate when they are used in combat.

The RPV components must have a long shelf life. An efficient packaging technique is needed, such as using plastic bags to seal the parts so they can withstand severe environments--let bags protect the RPV components from salt spray and moisture. Once an RPV is assembled, it is expected to be operational for only a short time so the severe requirements for corrosion resistance need not apply.

Design of RPV avionics is another area in which large savings could be obtained. RPVs will have many electronic components--comprising

perhaps 30 to 50 percent of the total cost, so considerable attention must be given to making them inexpensively. While they must have some reliability, the reliability we should be thinking of is in terms of flying the vehicle 10 to 20 sorties rather than for thousands of hours. Where practical, the concept of throwaway electronic equipment should be encouraged, such as that used for inexpensive transistor radios and integrated circuit designs. If an avionic unit does not check out, replace one black box by another--don't expend resources to repair bad ones. It is again clear that requirements established by military specifications and standards should not be applied to RPV electronic components, and, if commercial-quality elements are used, their price can be reduced by a large amount--by at least a factor of 10, and perhaps by a factor of 100. Costs may be substantially reduced if more optimum temperature and pressure environments are provided for electronic units in the design of RPV airframes. We could then expect satisfactory performance from many low-priced commercial-quality electronic components.

The RPV system should be designed to permit tests of various components before the vehicle is committed to the launch pad. Automatic go-no go tests for the RPV electronic components should be possible using AGE test equipment rather than equipment in the RPV. Also, the engine could be checked by measuring the pressure ratio of the compressor at a given rpm. This may be accomplished without starting the engine by rotating it to the desired rpm using an external power source. A simple check of the condition of bearings can be made by timing the period required to slow down between two rpm values.

Caution must be taken, however, for the essential functions of the vehicle to have some degree of redundancy or an alternate way of operating

without forcing costs too high or adding too much to the RPV's size and weight. As an example, the autopilot should have a self-contained mode of operation. If loss of radio contact occurs, the RPV could still fly to the starting point or other preprogrammed location.

Two major elements of RPV systems should not be compromised as far as quality is concerned. These elements are long-life-time items: the relay aircraft and control centers. The relay aircraft for most tactical combat scenarios using RPVs must be able to support a number of RPVs at the same time. It would be impractical in most cases to provide a drone relay for a single RPV, as it would reduce the reliability and increase the operating cost of the overall system. Therefore, a highly reliable manned aircraft should be used for the relay aircraft committed to service a number of RPVs. One relay station may be designed to concurrently handle three or four RPVs at the target transmitting television signals or other imagery and, in addition, eight or ten others enroute sending data using a narrow bandwidth and time-multiplex techniques. Thus a dozen or more vehicles can be airborne at the same time under the control of a single control center and through one relay aircraft. While the electronics in this relay aircraft would probably be complex and expensive, it would be unwise to chance losing it from noncombat reasons. It probably will remain behind the FEBA at a very high altitude to reduce its vulnerability and to provide a long line-of-sight range without horizon cutoff so RPVs can be flown at distances of 200 to 250 nautical miles from the relay aircraft. A U-2 or an RB-57F may be appropriate, or, if more payload and volume are required, perhaps a C-141 or other jet cargo aircraft having a loiter altitude of at least 40,000 ft should be

used. The relay aircraft may need to remain on station for long periods, such as 8 or 10 hours; thus one aircraft could conceivably support a hundred RPVs during the station period.

The other element of the RPV system which may also be expensive and needs considerable attention for efficient design is the ground control center. It should contain a general-purpose computer to provide versatility through appropriate software as changes occur in the control center functions or RPV designs. A number of control stations should be required within a center--three or four where the remote pilots control RPVs by imagery from onboard sensors, and another station with three or four people to monitor and control eight or ten other RPVs going to and from targets. There also may be a station for launch and recovery of RPVs. Therefore, a control center can be envisioned consisting of three or more trailers compatible with bare base or 407L equipment and transportable in a C-130 or other airlift aircraft.

The development and design of future RPV systems are endeavors which should not be skimped on with regard to costs and quality. Large overall savings can be obtained if sufficient R&D money is provided early in development directed to finding ways to reduce costs and to provide the basis for an appropriate logistics and maintenance system such as the one mentioned earlier. Experiments to realize throwaway components should be supported. Automated production techniques should be developed so the Air Force will have the capability to quickly mobilize after a production run on an RPV design has been discontinued. We should experiment with different materials and fabrication techniques to reduce the labor costs in the construction of vehicles. Various types of plastics and perhaps

epoxy and paper structures may be acceptable and most economical in certain areas.

Different techniques should be tried for launching and recovering all unmanned vehicles--drones as well as RPVs. Programs should be initiated to develop and evaluate new techniques in order to incorporate the best launch and recovery capabilities for future RPV designs. One way to save money on RPV operations is to reduce the requirement for support aircraft. The only aircraft needed in an RPV strike or strike support system is a relay aircraft. Ground launch and some type of ground recovery by a horizontal landing are predicted to be the least expensive and the most desirable methods, especially if many sorties are required of each vehicle in a short period of time. Unless unique requirements exist, tactical RPVs should not be constrained to launches from DC-130s and helicopters for recovery. The present techniques place excessively restrictive limitations on future RPV system designs.

The opportunity exists to obtain viable new tactical weapon systems at very low life-cycle costs. All methods should be investigated which can force the costs down as compared to those which would result from present aircraft methods and procedures. RPVs will have a short expected lifetime and will not require the reliability of man-rated systems. Therefore, today's aerospace standards, specifications, and practices and Air Force aircraft management procedures do not necessarily apply to RPVs. Large cost savings can be obtained if commercial quality components and materials are used and automated production techniques are developed. This approach can lead to throwaway components which in turn can revolutionize the maintenance and support required and effect a large reduction in life-cycle costs.